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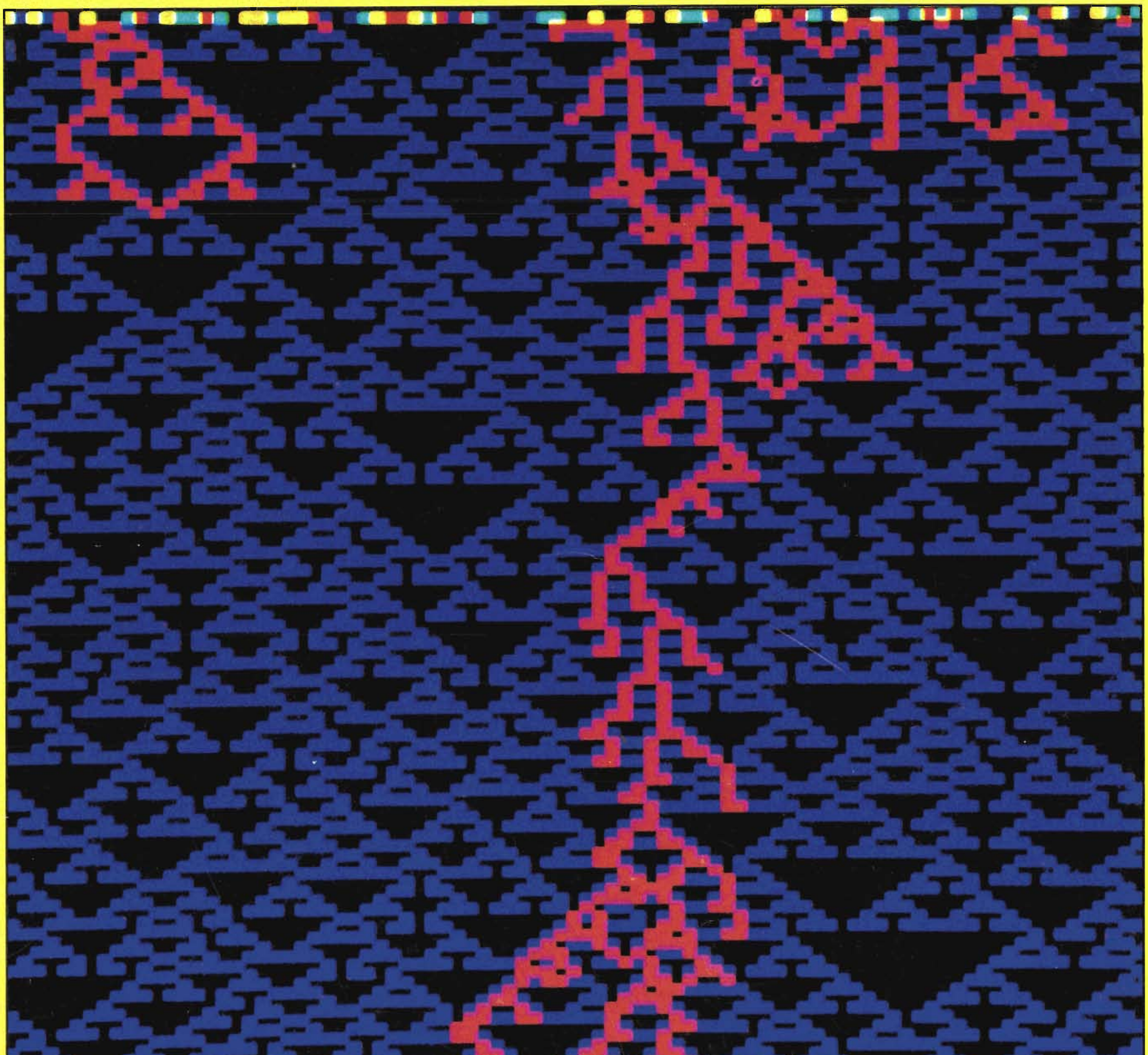
LOS ALAMOS NATIONAL LABORATORY



EDITOR'S NOTE

This issue is evidence of our growing ability to understand complex systems and the essential role that computers play in this increasing capability.

The title of the cover article, "Cellular Automata," refers to discrete mathematical systems that can provide a useful model for many complex natural systems—in particular, systems with many degrees of freedom that evolve in a more or less discrete fashion. The idea of such a construct grew out of von Neumann's interest in developing a theory of information encompassing both natural automata (living systems) and manmade automata (computer and communications networks). His work in automata theory in the late 1940s followed naturally from his pioneering work on the logical design of the new electronic automaton, the digital computer.

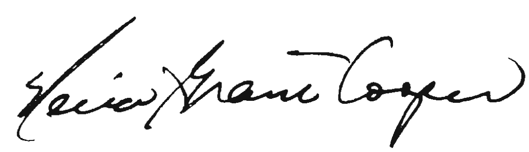
Cellular automata are in many ways directly analogous to parallel-processing digital computers and are therefore most easily investigated on digital computers. For many years research in this area was limited to a few isolated individuals, but recently scientists from a wide range of disciplines have become interested in this subject, in part because of increased access to computer facilities. Last March they came together at a Los Alamos conference to discuss both the intrinsic properties of cellular automata behavior and their possible use as models for natural systems. DNA sequences and their evolution, lattice-spin systems in physics, microtubules in biology, and complex chemical systems are among the applications already under investigation. One of the speakers and author of the cover article, Stephen Wolfram, has been credited by many as making this infant field into a science. His comprehensive study of one-dimensional automata has elucidated statistical features of self-organizing systems and has led to his discovery of four universal classes of behavior. This discovery may be a key to defining complexity as a quantitative concept.

In contemplating a general theory of complicated automata back in 1948, von Neumann asked this question: Is it possible to build automata that can create things more complicated than themselves in analogy with the processes of evolution? Genes contain, in some sense, a description of the whole organism, its replication, and its evolutionary change. What logical design underlies their operation?

Since then we have come to understand that DNA operates much like a programmed computer and that the genetic code is essentially the "microcode" that describes how the computer is run. But the basic flow chart that governs the operation and evolutionary development of a whole DNA molecule remains a mystery. As Walter Goad describes in this issue, one hope for greater understanding is comparative analysis of the many DNA sequences that are rapidly becoming known. Such analysis has been facilitated by the formation of GenBank, a national computer-based library of DNA sequences at Los Alamos, where scientists are not only collecting and annotating the library entries but also examining similarities among them with one of today's supercomputers, the Cray-1.

Our understanding of the natural automaton we call the gene is advancing through laboratory studies as well. In this issue scientists from the Life Sciences Division explain how they unraveled, step by step, the action of a particular gene cluster known as the metallothionein locus. This gene cluster, which defends against certain types of heavy-metal poisoning, contains an on/off switch that may be attached to other genes (such as the oncogenes implicated in cancer) to control their expression. The authors' elaborate and careful studies on the locus itself are now providing a sound basis for using it in such an exciting way.

The issue closes with a report on the recent conference sponsored by the National Security Agency and Los Alamos National Laboratory and entitled "Frontiers of Supercomputing." Among the Laboratory organizers of the conference were Bill Buzbee, Nick Metropolis, and David Sharp, who describe the quantum jump in computing that would be made possible by massively parallel computer architectures. This jump would have far-reaching impact on our national security and economy as well as on scientific research. The ability to tackle complex problems more realistically is the promise of the next generation of supercomputers and the key to progress in numerous activities of the modern world. ■



On the cover.
A space-time pattern of a one-dimensional cellular automaton generated on a computer by Stephen Wolfram. The automaton evolves from a random initial configuration (colored squares across the top) to exhibit class 3 behavior (pattern of blue squares) and class 4 behavior (pattern of red squares). For explanation of these universal behavioral classes see Wolfram's article, "Cellular Automata."

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